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Characteristics of Composite Nanofibers in the Sno_2-Zno And Sno_2-Tio_2 Systems as a Photoanodes in Dye-Sensitized Solar Cells

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EXTENDED ABSTRACT

ZnO-SnO_2 and TiO_2-SnO_2 composite nanofibers (CNFs) are synthesized by electrospinning a polymeric solution containing an equimolar concentration of the metals precursors and subsequent annealing. The composite formation is demonstrated by X-ray diffraction and energy dispersive X-ray measurements and morphology by scanning electron microscopy. Synergy in electronic and electrical properties are demonstrated by cyclic voltammetry, absorption spectroscopy, and electrochemical impedance spectroscopy. The TiO_2-SnO_2 and SnO_2-ZnO CNFs offer valuable properties when utilized as a photoanode in dye-sensitized solar cells in terms of photoconversion efficiency (PCE ~8.00%) and (~5.60%), respectively, compared to their binary counterparts SnO_2 (~3.90%), TiO_2 (~5.1%) and ZnO (~1.38%).

Recently, one-dimensional nanofibers materials, have been widely growing interest because of their fundamental scientific interest as well as their potential applications in functional devices [1-3]. Among them, nanostructured metal oxide semiconductors (MOS), tin oxide (SnO_2), zinc oxide (ZnO) and titanium dioxide (TiO_2) have demonstrated excellent performance in various technological applications [4, 5] such as; in dye-sensitized solar cells (DSSCs). However, currently, the interests are shifting towards the synthesis of more complex structures employing two MOS for a range of applications including photoelectrode in DSSCs. These coupled MOS overcome the limitation of a single MOS, such as core-shell and composite nanostructures which possess qualities of both the component oxides and permit

Two composite nanofibers materials and their counterparts were synthesized by electrospinning for the present study. The materials were synthesized using previously reported procedures [9]; the only difference in the synthesis of composite nanofibers is that 1:1 molar mixture of the metals oxide precursors was used. For fabrication of DSSCs, a paste of the nanofibers was prepared as reported before [9] and screen printed at an area of ~0.2 cm^2 on fluorine-doped tin oxide (FTO) as a working electrode. The films were dried at 100 °C and subsequently sintered at 450 °C. The sintered films were immersed for 24 h in 0.3 mM ethanolic solution of cis-bis(isothiocyanato)bis (2,20-bipyridyl-4,40-dicarboxylato)-ruthenium(II) dye (N719). A platinized FTO glass substrate was used as the counter electrode. DSSCs were obtained by assembling the working and counter electrodes separated by a 50 µm thick plastic spacer (Suryln); the electrolyte (iodide/triiodide redox couple) was then injected into the spacer region. Photocurrent measurements of the fabricated cells were carried out at AM 1.5G (100 mW cm^{-2}) using a solar simulator (SOLAR LIGHT, Model 16-S 150) employing single port simulator with power supply (XPS 400). The current-voltage (I-V) curves of the devices were recorded using a potentiostat (Autolab PGSTAT30, Eco Chemie B.V., The Netherlands).

Figure 1(a) shows the current density (J) vs. voltage (V) plots for the DSSCs fabricated using SnO_2-TiO_2 CNFs and SnO_2-ZnO CNFs photoanodes and its counterparts. The PCE of the CNFs based device was increased by ~100% than SnO_2 based device and over ~50% than the TiO_2 based device. The V_{OC} of the SnO_2-TiO_2 CNFs based device shifted towards that of TiO_2 and their short-circuit current density (J_{SC}) towards that of SnO_2, i.e., a synergy has been achieved in the SnO_2-TiO_2 CNFs-based device [8]. Similarly, the SnO_2-ZnO CNFs photoanode has shown superior performance, V_{OC} ~ 0.738 V, J_{SC} ~ 13 mA cm^{-2}, FF ~ 0.6 yielding PCE of 5.6% Figure 1(b). The PCE of the composite based device has been increased by ~400% than ZnO based device and over ~30% than the SnO_2 based device. Therefore, the present combination in the composite could prevent the ZnO degradation which can be observed on the improvement of J_{SC} and FF composite based device. Therefore, CNFs is shown to have beneficial properties when used as a photoanode in DSSCs. Thus, this study shows a simple composite electrode design in enhancing the functional performances of the final device.

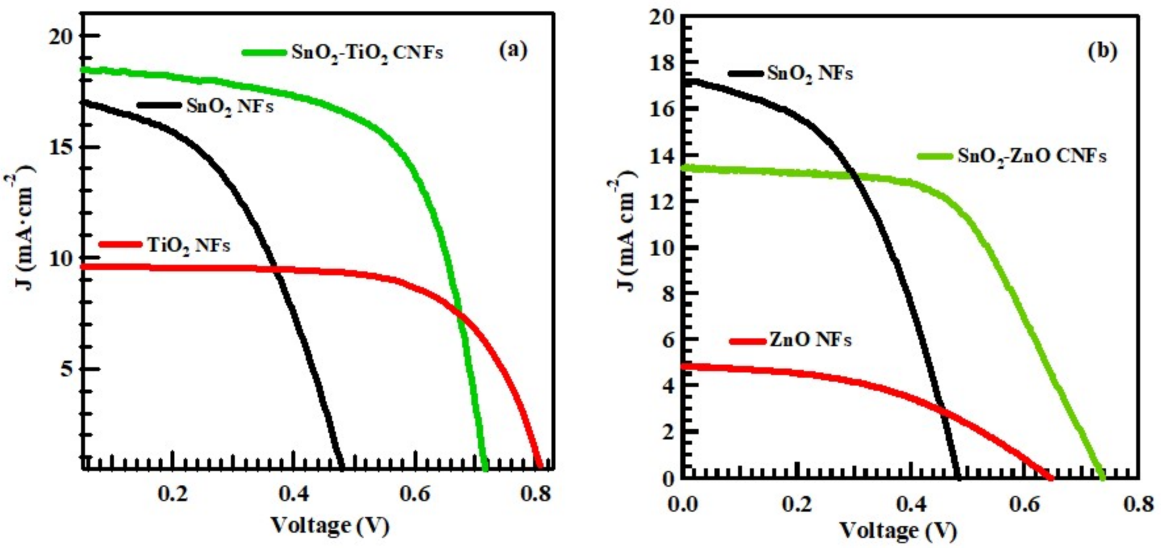

Fig. 1: (J–V) curves of the solar cells fabricated devices using: (a) the TiO_2 NFs, SnO_2 NFs, and SnO_2-TiO_2 CNFs under 1 sun condition and (b) ZnO NFs, SnO_2 NFs, and SnO_2-ZnO CNFs under 1 sun condition. All the photoanodes were sensitized for 24 h.

Keywords: One-dimensional hybrids; Electrochemical materials; Photovoltaics; Energy conversion materials.

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References

[1] Barth S., Hernandez-Ramirez F., Holmes J.D., Romano-Rodriguez A. (2010) Synthesis and applications of one-dimensional semiconductors, Prog. Mater Sci. 55(6):563-627.
[2] Zhai T., Yao J. (2012) One-dimensional nanostructures: principles and applications, John Wiley & Sons.
[3] Zhang Y., Park M., Kim H.-Y., El-Newehy M., Rhee K.Y., Park S.-J. (2015) Effect of TiO_2 on

photocatalytic activity of polyvinylpyrrolidone fabricated via electrospinning, Composites Part B 80:355-360.
[4] Wei Q., Xiong F., Tan S., Huang L., Lan E.H., Dunn B., Mai L. (2017) Porous One-dimensional nanomaterials: design, fabrication and applications in electrochemical energy storage, Adv. Mater. 29(20):1602300.
[5] Kuchibhatla S.V., Karakoti A., Bera D., Seal S. (2007) One dimensional nanostructured materials, Prog. Mater Sci. 52(5):699-913.
[6] Sujinnapram S., Moungsrijun S. (2015) Additive SnO_2-ZnO composite photoanode for improvement of power conversion efficiency in dye-sensitized solar cell, Procedia Manuf. 2:108-112.
[7] Mao X., Zhou R., Zhang S. , Ding L., Wan L., Qin S., Chen Z., JXu J., Miao S. (2016) High efficiency dye-sensitized solar cells constructed with composites of TiO_2 and the hot-bubbling synthesized ultra-small SnO_2 nanocrystals, Sci. Rep. 6:619390.
[8] Bakr H. Z., Wali Q., Ismail J., Elumalai K. N., Uddin A., Jose R. (2018) Synergistic combination of electronic and electrical properties of SnO_2 and TiO_2 in a single SnO_2-TiO_2 composite nanofibers for dye-sensitized solar cells, Electrochim. Acta, 263: 524-532.
[9] Wali Q., Fakharuddin A., Ahmed I., Ab Rahim M.H., Ismail J., Jose R. (2014) Multiporous nanofibers of SnO_2 by electrospinning for high efficiency dye-sensitized solar cells, J. Mater. Chem. A 2(41):17427-17434.